I WAS interested to read Mr. Watson's lucid account of a simple constant current circuit (August issue p. 403). It may be worth commenting on the versatility of the circuit described: with slightly different external connections, the same circuit is widely used as a voltage regulator, and its use as an impedance converter has also been described (e.g. *Electronics*, May 3rd, 1963; *Electronics Letters*, March, 1965). I would like to comment briefly on some points of difference between Mr. Watson's circuit and a similar one which I developed some three years ago.

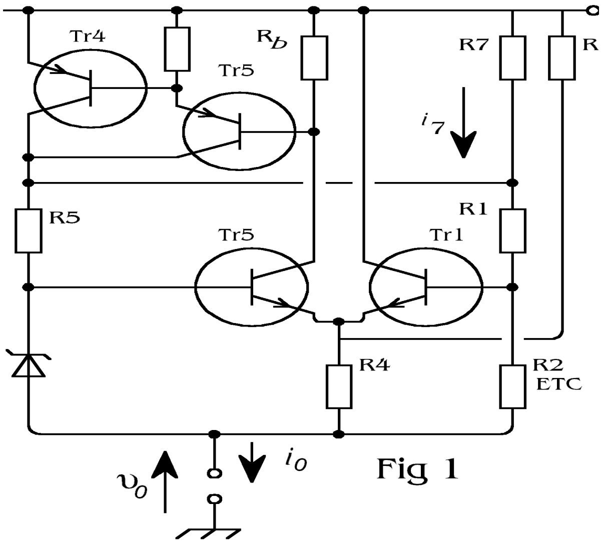

Fig 1

(1) No allowance is made in Mr. Watson's circuit for manufacturing tolerances in *hfe* of transistor Tr3. Of course Tr3 operates at constant collector current, so that its base current (supplied by Tr2 collector) will vary, from circuit to circuit, over a range which could, be 4:1 or more. This will result in considerable unbalance between the emitter currents of Tr1 and Tr2 (unless the value of R4 is adjusted individually). It is preferable to replace Tr3 by a Darlington pair Tr4-5 (my Fig. 1 arranging that the base current of Tr5 is fairly small compared with the current in *Rb*. This gives better defined working points, plus some increase in loop gain.

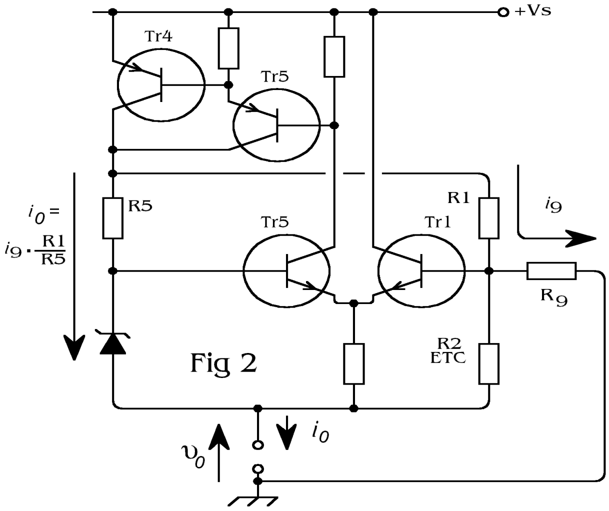

Fig 2

(2) Omission of the base return resistor for Tr3 is undesirable, and the reason given for its omission is not valid. Satisfactory starting of the circuit may be obtained e.g. by using a resistor R7 (see my Fig. 1). This resistor can also help, to reduce the dissipation in Tr3 (or Tr4) the current (i_7) through R7 will increase as the supply. voltage increases, but the output current is held virtually constant by the negative feedback loop, so that, as i_7 increases; Tr4 collector current falls. The small unbalance in Tr1-2. demanded by this can be minimized by the addition of R8, which takes current equally from Tr1 and Tr2 as the supply voltage increases.

(3) In my application, the circuit was required to operate as a negative impedance converter, as well as providing a constant bias current. This was achieved by the addition of one resistor (R9 my Fig. 2). The value of negative resistance appearing at the output terminals can be calculated very simply as follows. Application of a small increase of voltage υ to the output terminal will raise the potential of Tr2 base, and thus Tr1 base also, by precisely υ volts (assuming infinite loop gain). Therefore, a current $i_9 = \upsilon/R_9$ must flow through R9, and this current must be drawn entirely from R1 (because the potential across R2 etc. is fixed). The resulting change across R1 appears across the whole bridge, and will result in an increase in output current of $i_0 = i_g \times \frac{R_1}{R_5}$,

so the effective output resistance

$-R_n = \frac{v}{I_O} = \frac{R_9 . R_5}{R_1}$. Production versions of this circuit show very satisfactory stability of both i_0 and R_n.

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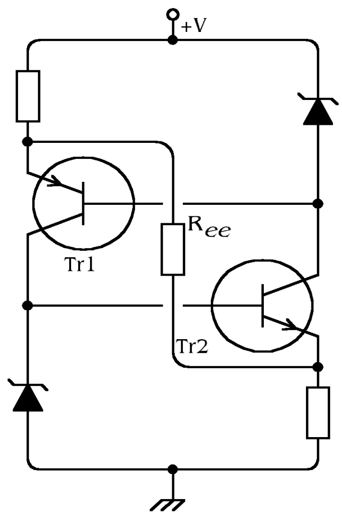
JOHN WILLIS

THE elegant complementary transistor current stabilizer which Mr. P. Williams describes in his letter in the September *Wireless World*, p. 456, has an impedance of $Z = r_{c1} \| r_{c2} \| R_{bb}$, where R_{bb} is the value of the starting resistor between the bases of the two transistors which he states may not normally be needed.

May I offer as an improvement the introduction of a resistance R_{ee} as shown here.



A change of voltage $+\Delta V$ will cause a current change of $+\Delta V/R_{ee}$ to flow through this resistor, but each transistor will then pass this amount less current. The net effect is that the original voltage change causes a current change of

$+\Delta \frac{V}{R_{ee}} - \frac{2\Delta V}{R_{ee}}$ through the circuit.

The value of Ree can thus be chosen to cancel the effects of R_{bb} and the two r_c terms, or to exceed them and so give a two-terminal negative resistance device.
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(Continued on page 611;)